Comparison of mass wasting processes on Vesta and Ceres. R. Parekh[1,2], K. Otto [1], R. Jaumann [1,2], K.D. Matz[1], T. Roatsch[1], E. Kersten[1], F. Preusker[1], C. Raymond[3]. [1]DLR Institute of Planetary Science, Berlin, Germany, [2]Freie University of Berlin, Germany,[3]Jet Propulsion Laboratory, California, USA. (rutu.parekh@dlr.de).

Introduction: The Dawn mission has significantly enhanced our understanding regarding surface and subsurface geological processes on Vesta and Ceres. The ample amount of high resolution imaging and spectral data has improved our knowledge with respect to formation of small bodies, their evolution and current state [7, 12, 2, 17]. Earlier studies of mass movements on Vesta focus on the southern latitudes where the giant Rheasilvia impact basin is responsible for a high topographic relief representing ideal mass wasting conditions [8,9]. On Ceres, fluidized mass movement helped to assert the presence of water ice at shallow subsurface at global scale [15,3,6]. Using above finding as a base, we extend these studies by classifying [10] and comparing the mass movement behavior under similar gravity but compositionally different conditions present on Vesta and Ceres. Vesta being dry [7] and Ceres with water ice on shallow surface [17] may introduce differences within its landslide properties.

Data and methods: To identify mass wasting processes we used mosaics of the Low Altitude Mapping Orbit (LAMO) (~20 m/pixel for Vesta and ~35 m/pixel for Ceres) and High Altitude Mapping Orbit (HAMO) (~70 m/pixel for Vesta and 140 m/pixel for Ceres) from Dawn framing camera images [13,14]. To understand the material mobility of landslides we analyzed their drop height (H) and run out length using HAMO digital terrain model (DTM) mosaics with ~92 m/pixel and ~135 m/pixel resolution available for Vesta and Ceres respectively [11].

Results: We identified three major classes of landslides based on our morphologic analysis of Vesta and Ceres: slides, rotational slumps, and fluidized movements[10]. The differences in morphology may be quantifiable by comparing geometrical properties of landslides statistically. The friction coefficient -ratio of mass wasting fall height and run-out length (H/L) is an example of such:

Friction Co-efficient (H/L). The relationship between friction coefficient (H/L) and run-out length (L) of the deposit constrain the dynamics and landscape formation. In Figure 1 we compare the coefficient of friction of different types of mass wasting process identified on Vesta and Ceres. From the graph we conclude: (1) The friction coefficient (H/L) of landslides Vesta and Ceres, follows an approximate linear trend with run-out length (L) in a double logarithmic plot; (2) for a given run-out length, there is no strong relationship between run-out length (L) and the coefficient of friction (H/L) on both bodies; (3) on Ceres there is a larger relative abundance of landslides with run-out length exceeding 10 km compared to Vesta; even though Vesta has higher topographic relieve (40 km and 9 km on Vesta and Ceres, respectively). On Vesta, the majority of landslides terminates on shorter distance in comparison to Ceres, where the longest ones travelled up to ~80 km in distance. Within Ceres, highest H/L values are found for landslides classified as slides whereas on Vesta the highest H/L are found for fluidized movements where deposits terminates on shorter distances.

Discussion: Large range of friction coefficient may explain rheological differences of mass wasting material. Previous analysis of friction coefficients describe the behavior of some Cerean flows near to flows on Iapetus[15]. The range of H/L on Iapetus is explained by the presence of slippery ice near the upper layer of the surface [16]. After incorporating our readings, we confirm that large span of friction coefficient values are present for a given run-out length for both, Vesta and Ceres. This points towards the possibility that ice in the regolith is not the only geological process involved. Further, we investigated the maximum amount of energy released during the mass movements and analyse if it would be sufficient to create melt on Ceres or not. The equation required to calculate specific energy to melt the ice is [18];

$$E_m = C_p (T_f - T_a) + \zeta \qquad (1)$$

Where C_p = specific heat capacity of ice (2.108 kJ $kg^{-1}K^{-1}$), T_f = freezing temperature of ice (273.15 K), Ta = surface temperature on Ceres (150 K) [2], and ζ= latent heat of fusion (334 $kJkg^{-1}$) [17]. Next, we estimate the released energy (E_r). Given a fall height H and the surface acceleration of g = ~0.27 ms^{-2} on Ceres[4],

$$E_r = gH \qquad (2)$$

For Ceres E_r = 0.06-0.88 $kJkg^{-1}$.The energy required for melting pure ice on Ceres is around 594 $kJkg^{-1}$ [Eq. 1]. E_m is of higher order magnitude than the estimated E_r. The large difference consequently does not allow the ice in the regolith to melt, however ice particles may locally reach higher temperatures along the landslide bases [1]. Furthermore, the presence of carbonates within the material may reduce the melting temperature of the ice [3]. Thus, water ice melting may still be possible and may generate fluidized movements with longer travel distances. However, we cannot apply the same model to Vesta as it is an overall dry [7] and does not comprise many volatile materials. The lack of water ice may generate shorter lobate movements compared to Ceres. High velocity impacts of around 8-10 m/s are possible on Vesta [19] which may have released enough energy to create such movements in forms of ejecta blankets. Furthermore, we also compared the coefficient of friction of mass wasting features on Vesta and Ceres to other planetary bodies. Traditionally the friction coefficient is compared to mass wasting processes of Earth and Mars [15,16]. However, to investigate influences of the volatile content, we compare the friction coefficient of Vesta (0.05-1.6) and Ceres (0.001-0.95) with planetary bodies of similar surface accelerations which includes Iapetus [0.22 ms^{-2}], Rhea [0.264 ms^{-2}] and Charon [0.27 ms^{-2}] in Figure 2. Note that all these bodies are volatile-rich with a water ice regolith but are colder than Vesta and Ceres [15,1]. Although Vesta has dry brittle materials, the friction coefficient falls within a similar rage as rest of the volatile rich bodies (Figure 2). This shows that investigations solely based on the H/L measurement may not be always suitable to predict the mass wasting mechanisms and surface composition.

Summary: The relation between the friction coefficient (H/L) and run-out length (L) is not a reliable tool to depict the material composition on Vesta and Ceres, as we identified a similar relation between the two parameters even though both the asteroids have significant differences in surfaces composition. Based on our morphologic analysis and geometry measurements, we understand that mass wasting features on Vesta are small in length, whereas Cerean mass movements extends up to longer distances, and cover larger areas probably due to the abundance of ice mixed within the regolith.

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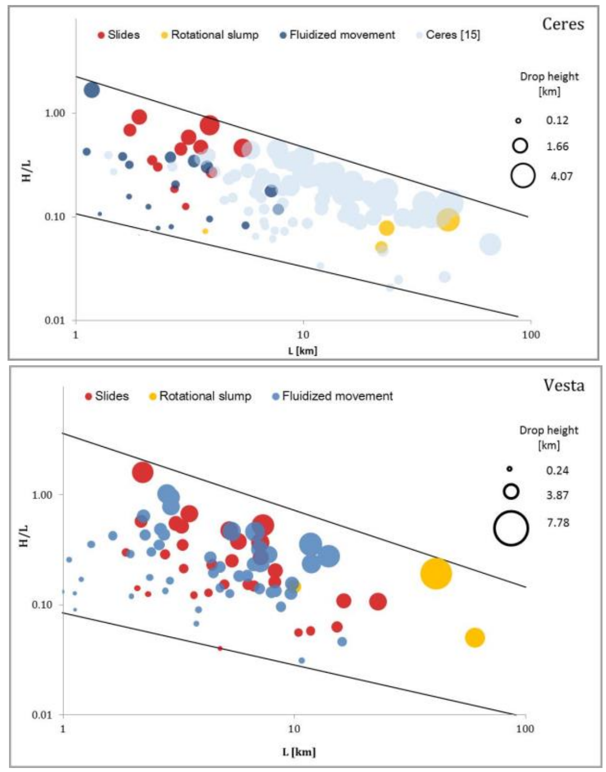

Figure 1. Landslide mobility on Vesta and Ceres. Shown is the measurement of the friction coefficient and run-out length of three different types of mass movements. The size of each dot correspond to the drop height of the deposit. The black lines mark the range of H/L values for a given run-out length and are for orientation only. Axis in double logarithmic scale

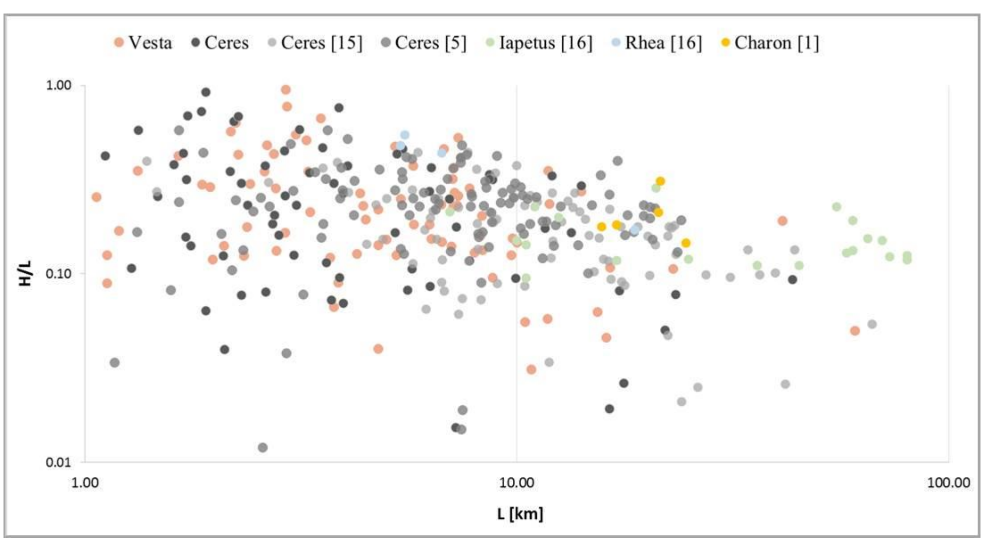

Figure 2. Comparison of landslide mobility with other planetary bodies (note the double logarithmic scale). The identified mass wasting features on vesta and Ceres are compared with lobate blocky land-slides on Iapetus [16], long run-out slides on Charon [1] and intra-crater slides of Rhea[16]. Small Vesta landslides exhibit an overall higher friction coefficient (possible image resolution effect) whereas Cerean slides travel up to the longer distances.